WHAT IS LEFT AFTER THE TANBARK IS REMOVED.

Sometimes the logs are used for cordwood; often they are left to burn in the redwood logging operations.

Issued September 20, 1911.

U. S. DEPARTMENT OF AGRICULTURE,

FOREST SERVICE—BULLETIN 75.

HENRY S. GRAVES, Forester.

CALIFORNIA TANBARK OAK.

PART I. Tanbark Oak and the Tanning Industry.
By WILLIS LINN JEPSON, Collaborator.

PART II. Utilization of the Wood of Tanbark Oak.
By H. S. BETTS, Engineer in Timber Tests.

APPENDIX. Distribution of Tannin in Tanbark Oak.
By C. D. MELL, Assistant Dendrologist.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Forest Service,
Washington, D. C., March 13, 1911.

Sir: I have the honor to transmit herewith a manuscript entitled "California Tanbark Oak," by Willis Linn Jepson, collaborator, and H. S. Betts, engineer in timber tests, together with an Appendix by C. D. Mell, assistant dendrologist, and to recommend its publication as Bulletin 75 of the Forest Service. This bulletin shows how the complete product of tanbark oak—its bark and its wood—may be utilized. It is important that this complete utilization should be brought about. The wood is now left in the forest to rot unused or to add fuel to forest fires. The timber tests show that the lumber has a high value and can be put to the same uses to which the eastern oaks are put. A careful handling of woodlands, coupled with conservative lumbering, ought to make the tanbark-oak crop continuous and render this resource inexhaustible.

Respectfully,

Henry S. Graves,
Forester.

Hon. James Wilson,
Secretary of Agriculture.

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CALIFORNIA TANBARK OAK.

PART I.—TANBARK OAK AND THE TANNING INDUSTRY.[1]

By Willis Linn Jepson.

DEVELOPMENT OF THE TANNING INDUSTRY IN CALIFORNIA.

Tanbark oak is, economically, the most important of the 15 Pacific coast oaks, because it furnishes the chief material used in the extensive tanning industry of that region. In 1900, according to the census, California ranked third among the States in the value of tanned hides produced. Commercial tanning on the Pacific coast began with the influx of Americans into California in 1849 and 1850. As early as 1852 Sonoma County had one tannery which produced $30,000 worth of leather, and by 1856 there were 18 in the State, in which $94,000 was invested. The bark of the tanbark oak was first used at Santa Cruz, and in 1857 a tannery there with an output of 700 hides a month was the largest in the State. Its leather was superior to that produced by the establishments which still used the live-oak and black-oak bark, the first utilized. By 1859 there were 29 tanneries and their product was more than sufficient for home consumption. In the next year the value of the output of the State's tanneries was $276,014, and seven years later, in 1867, there were more than 40 establishments, with an annual product worth $400,000.

The development of the tanbark industry since 1850 is shown by Table 1.

Table 1.—*Tan oak bark harvested in California, 1855 to 1907.*

Annual product.		Annual product.		Product by periods.	
Year.	Cords.	Year.	Cords.	Years.	Cords.
1855	1,000	1893	20,000	1851–1860	15,000
1860	3,000	1895	20,000	1861–1870	55,000
1870	8,000	1900	25,000	1871–1880	147,500
1875	15,000	1904	30,000	1881–1890	240,000
1880	21,000	1905	25,000	1891–1900	218,500
1881	24,000	1906	30,000	1901–1907 (7 years)	185,000
1890	24,000	1907	20,000	1851–1907	861,000

[1] In gathering the data upon which this report is based the author received assistance and helpful courtesies from many people directly or indirectly connected with the tanbark industry on the Pacific coast. Their number was too great to permit of individual acknowledgment here, but the author takes this means to thank them for the great assistance given him.

At $18 per cord, an average of the prices since 1850, the value of the bark produced in the period 1851–1907 would be $15,498,000. Practically all of this has been consumed in the manufacture of heavy leather used for belting, harness, saddles, and soles. The California tanneries, up to 1907, turned out 250,000,000 pounds of such leather, valued at $75,000,000.

SILVICAL CHARACTERISTICS OF THE TANBARK OAK.

Tanbark oak (*Quercus densiflora* H. & A.) grows to be from 50 to 140 feet high and from 1 to 6 feet in diameter. There are four general forms of growth—the roundheaded; the spire-shaped, similar to coniferous trees; the shrubby, deep-shade form; and the stunted chaparral form. In open situations, or in association with madroña and California black oak, the main trunk subdivides into a number of large branches and forms a rounded head, although the height of the crown is greater than its width. In dense, coniferous forests it assumes the spire or cone shape of the trees with which it is associated, and these trees are tallest and have the straightest trunks, with a clear length of from 30 to 80 feet. Under stands of mature Douglas fir or redwood there may be abundant low, shrubby growths of tanbark oak, since the tree is remarkably shade enduring, and when the dominant forest cover is removed the tanbark oak promptly takes possession of the logged areas. This is exemplified especially on the Mendocino coast. In the interior of California, around Mount Shasta, the stunted tanbark oak in the midst of chaparral assumes many of the characteristics of the shrubs by which it is surrounded, such as low stature, rigid branches, and small, thin leaves. This chaparral form (var. *echinoides*) is worthless for tanbark.

Tanbark oak has many chestnutlike characteristics. In the character of its male flowers the tree is a chestnut, but in the character of its female flowers and in its habit it is an oak. By some authors it is referred to the genus *Pasania*, which includes nearly 100 species in southwestern Asia.

The oaklike characters and the chestnutlike characters are compared in the following tabulation:

CHESTNUTLIKE CHARACTERS.	OAKLIKE CHARACTERS.
Parallel nerves of the toothed leaves.	Bark very like typical oak bark.
Erect catkins.	
Pistillate flowers in same catkins as staminate.	Involucre 1-flowered.
Stamens of male flowers very much exceeding calyx; rudiments of stamens in pistillate flower.	Ovary 3-celled.
Acorns with suggestion of burriness. Nut often vaguely triangular.	Cup of the acorn a true cup and not a closed involucre. Kernel oaklike, bitter to the taste.

The chestnutlike leaves are from 2 to 5 inches long and are borne on short petioles. The teeth are small and scattered. Sometimes the margin is entire near the base or even for its whole extent, especially on narrow-leaved forms. This variation in leaf form sometimes leads woodsmen to speak of "two kinds of tanbark oak." Both surfaces of the leaf, especially the lower, are covered with a thick, light-colored, dusty fuzz, which gives the foliage a distinctive hue.

The flowers, which appear in July or August, often conceal the foliage with a mass of grayish-white blossoms. The acorns are from $\frac{3}{4}$ inch to $1\frac{1}{4}$ inches long, and from $\frac{3}{4}$ to 1 inch broad, and coated with a brown fuzz. The somewhat burrlike but shallow cup is covered with long and narrow scales.

The bark of the trunk of adult trees is usually from 1 to 3 inches thick, and sometimes from 4 to 5 inches; it is brown, smooth on the surface, but so fissured longitudinally and transversely as to produce elongated, irregularly rectangular plates. On the main limbs and on young trunks the bark is very smooth, little fissured, if at all, white, gray, or mottled, and often strikingly similar to the bark of red alder.

RANGE AND OCCURRENCE.

The range of tanbark oak extends from a little north of the Umpqua River in southwestern Oregon through the coast ranges to Santa Barbara in California, and from the Humboldt region eastward by way of the Shasta Mountains to the Sierra Nevada, and along that range as far south as El Dorado County.

In general, though not always, tanbark oak grows either with redwood or in the neighborhood of the redwood belt. It is an associate of redwood in all the great redwood areas and even in the isolated bodies or tongues in the range of that tree. The greatest forests of redwood are in Mendocino and Humboldt Counties, and in those counties tanbark oak attains its best development. (Pl. II.) Tanbark oak is not at its best, however, in the heart of the redwood forests, but in the belts which border them. The principal body of tanbark oak forms a band along the inland side of the redwood belt and covers the "Bald Hills." The general term "Bald Hills" is a widely used folk name for the inland portion of the seaward Coast Range, that much-broken mountain range which parallels the coast and separates the ocean from such valleys as those of Santa Rosa, Alexander, and Ukiah, and the narrow canyon of the main Eel River in its long course from Little Lake Valley northward to Humboldt.

The higher inner ridges and summits and the interior slopes are covered by a mixed forest forming the tanbark oak belt along the whole length of the main redwood body. In southern Humboldt,

however, the tanbark oak belt pushes through the great transverse break in the redwood belt at that point, and an arm extends northward over the Wilder Ridge country to the Rainbow Range. This extensive and excellent virgin body borders the redwood belt on the outside and covers a considerable portion of the Mattole country lying between the redwood belt and the ocean.

In the region around Eureka the redwood stand is so exceedingly dense that it practically occupies the whole country to the exclusion of tanbark oak. In the redwood forests along the main Eel River, on the Mad River, and on Smith River tanbark oak grows not at all or merely as rare individuals. Here it is necessary to pass through the redwood belt, or, what is usually the same thing, to gain the summits of the ridges at the headwaters of the coast streams, to find tanbark oak. To the south this is not the case. In Mendocino County tanbark oak occurs throughout the redwood belt. There, however, tanbark oak trees in the main redwood stands are usually small and scattering, and it is only on the summits above the redwood, and particularly on the inner summits and ridges, that the trees are abundant and of large size.

ASSOCIATES.

Tanbark oak never forms a pure stand. The tanbark oak belt consists of a mixed forest of broadleaf and coniferous trees. Its most common associates besides redwood are Douglas fir, which, except in Santa Barbara County, occurs with it throughout its range; madroña (*Arbutus menziesii*), its most common associate, which reaches very large dimensions in the tanbark oak belt; Oregon post oak (*Quercus garryana*), the most abundant of the true oaks in the whole tanbark oak belt; California black oak (*Quercus californica*), on all the higher ridges, or high, fertile hill slopes; and western chinquapin (*Castanopsis chrysophylla*), an associate in the regions of its best development.

THE PRODUCTION OF TANBARK.

CENTERS OF THE INDUSTRY.

The Santa Cruz district has been, from the first, one of the most important sources of tanbark, because the tanneries at Santa Cruz, San Jose, Santa Clara, and Redwood City could be supplied by wagons direct from the woods, and this obviated long and costly shipment by rail or water. Seventy-five per cent of the original stand has been peeled, but recently second-growth trees have begun to furnish a bark which is acceptable to tanners. Sonoma County has been an important source for 30 or 40 years, and its status now is about the same as that of the Santa Cruz district. For the

TYPICAL TANBARK OAK COUNTRY, WHERE, IN THE REDWOOD BELT, THE TREE ATTAINS ITS BEST DEVELOPMENT.

last 17 years the chief source has been the Mendocino district, along the coast to the north of Sonoma, where tanbark has been outranked only by redwood as a valuable forest product. This region has furnished probably more bark than all others put together, but 45 per cent of the stand has been peeled now and a considerable portion of the remainder is, under present conditions, too inaccessible to be of value. The stand in the Santa Lucia Mountain region, along the coast in Monterey County, which, though of excellent quality, was never large, is now almost exhausted. In the isolated Santa Barbara district and in the Sierra Nevada territory the trees are few and scattered.

The most extensive bodies of virgin tanbark oak now are in the north—in northern Mendocino and Humboldt Counties—and because of accessibility to shipping the main sources of supply are in the coast region of Mendocino, southern Humboldt, and, to some extent, Sonoma Counties in California, and in southwestern Oregon. The Sonoma and Mendocino areas have been drawn upon from the interior, also, by a railroad which follows the valleys of Santa Rosa, Russian River, and Little Lake northward, and has now reached the center of Mendocino County. The most northern part of the belt has not been much disturbed, since the railroad has not reached it and its distance from the ocean necessitates a long haul. The tanneries at Humboldt Bay have been supplied from Kneeland Prairie and the Acorn region in the Bald Hills country.

STAND AND YIELD.

It is estimated that there are now 1,425,000 cords of standing bark in the Pacific coast forests, distributed as follows:

Counties.	Cords.
California:	
San Mateo, Santa Cruz, and Monterey	100,000
Marin, Sonoma, and Napa	70,000
Mendocino	320,000
Humboldt, Trinity, western Siskiyou, and Del Norte	875,000
Oregon:	
Curry and Coos	60,000
Total	1,425,000

At the present rate of consumption, this is enough to provide for the needs of the leather industry in California for a little less than half a century.

The average yield of bark is from 200 to 350 cords per "claim," or quarter section (from 1¼ to 2⅛ cords per acre). From 350 to 640 cords (from 2⅛ to 4 cords per acre) is considered a particularly good yield, and exceptionally fine quarter sections yield from 640 to 1,200 cords (from 4 to 7½ cords per acre). The highest yields are not

uncommon in the best parts of the southern Humboldt and northern Mendocino district, where the stand in limited areas is nearly pure tanbark oak. The largest amount of bark ever reported from one "claim" was 1,284 cords, or 8 cords per acre.

In estimating tanbark in the Santa Cruz, Mendocino, and southern Humboldt districts cruisers generally count 6 trees to the cord, though sometimes the trees are so large that it takes only 4 to produce a cord. In the northern Humboldt district 8 or 9 trees make a cord and in the Klamath 14. Cruisers are more likely to underestimate than to overestimate a claim. Exceptionally large trees with thick bark produce from 2 to 3½ cords of bark. The figures given in Table 2 are from trees on the inner edge of the redwood belt.

TABLE 2.—*Amount of tanbark on oak trees of different sizes.*

Diameter	Height.	Length of peeled trunk.	Diameter of peeled trunk at upper end.	Age.	Weight of bark.	Dry weight of bark (calculated).
Inches.	*Feet.*	*Feet.*	*Inches.*	*Years.*	*Pounds.*	*Pounds.*
4- 9	30- 50	4- 8	3- 6	20- 40	15- 80	10- 70
10-12	40- 80	16-32	5- 8	40-100	80- 350	70- 250
13-18	80-100	32-65	7-12	70-125	350- 900	250- 650
19-24	90-120	65-80	7-11	100-159	900-1,700	650-1,200
24-36	115-140	80-95	9-11	125-180	1,700-2,500	1,200-1,800
36-48	100-120	80-90	9-18	150-210	2,500-4,000	1,800-2,800
48-60	100-120	80-90	9-18	170-250	3,500-8,000	2,500-5,700

To avoid discrepancies due to loose piling, the "cord" used in selling tanbark is reckoned by weight rather than by dimension, and is approximately a ton, though it varies in different localities from 2,200 to 2,600 pounds. It is most commonly 2,400 pounds, which is the standard accepted in San Francisco. For bark that has been peeled a year, 2,300 pounds is considered a ton. Very rarely a cord is measured by dimensions; but where it is, as at Arcata, for instance, it is 8 feet long, 4 feet wide, and 4½ feet high.

PEELING.

The peeling season runs from about May 20 to about August 10, but varies with latitude, weather, and locality. Peeling can be started any time after the sap begins to run and continues during the period of summer growth. Tanbark oak is extremely sensitive to heat and cold as regards the adhesion of its bark. A cold spring delays the opening of the peeling season and a cool, moist summer prolongs it. Trees on the shady north slopes will peel later than those on the ridges or south slopes, but one of the periodic north winds of the Coast Range, which are hot and dry, will make peeling difficult or cause some trees to bind down completely. Cold nights, on the one hand, will make the bark stick, and a hot period in July or August will put an end to peeling. Trees standing side by side often

show different sensitiveness to weather changes; even two sides of a tree may differ in ease of peeling and the north side stick before the other.

Peeling is also affected by injury from fire, wind, or snowstorms. Trees which are only slightly hurt by fire will not peel for two or three seasons, and sometimes not at all. The wounds made when limbs are broken off by windstorms or by the weight of snow have a similar effect. Even the "try marks" on trees which are found not ready to peel interfere with satisfactory work later in the season.

Peeling can be done more economically in the latter part of the season because the bark, which is brittle in the early part, becomes tougher then, so that it can be taken off in entire pieces.

At least half a day is required for two men to peel a large tree. The peelers, therefore, never begin late in the day upon a tree which they must leave unfinished until the next morning, as the bark may "bind down" overnight.

The peelers work in pairs. Usually they rely on the woodsman's one-edged ax alone, as they believe that the advantages of a spud do not equal the saving of time when the ax alone is used. With the blade of his ax the peeler tries the bark to determine if it is loose, and if it is he cuts two circles through the bark, one at the foot of the trunk, the other 4 feet above. The bark is then slit longitudinally and taken off in from one to four pieces. (Pl. III.) The circle of bark thus removed is called a "rim" or a "coil." The first coil is removed from the standing tree because it is easier to work when the tree is erect and because it prevents the loss in chips at the base of the tree, where the best bark is. In felling, the woodsman takes advantage of the lay of the land, of down logs, and of gullies, in order that the trunk may not lie flat on the ground and interfere with the removal of the bark. Most tanbark oak trunks are badly fire-hollowed, which makes it difficult to place them accurately. After the tree is down the small branches are lopped and interfering shrubs are brushed out. One man then goes ahead "ringing," or cutting through the bark around the trunk; the second man follows, slits the bark, and removes the coils. This process is continued up the trunk until the bark becomes less than one-half inch thick. As the "coils" are taken off they are laid on the ground with the inner or "flesh" side up, where, as they become dry, they harden and curl up.

The average woodsman peels from 1 to 1½ cords per day. Where the stand consists of trees with straight, clear trunks standing on ridges, an expert peeler can cut from 4 to 5 cords in a day. In the case of very limby trees it is a general practice to take the bark off only the clear portion of the trunk and abandon much of the remaining bark even where it is thick. The quality of such waste is shown by the analyses given in Table 3.

TABLE 3.—*Analyses of bark wasted in abandoned tops.*

Origin of samples.	Solids soluble in cold water.			Solids soluble in hot water only, reds.	Total solids.
	Tannin.	Non-tannin.	Total.		
1. Sample taken 3 feet beyond last coil removed by peelers	*Per cent.* 17.29	*Per cent.* 13.08	*Per cent.* 30.37	.....	*Per cent.* 30.32
2. Sample taken 8 feet beyond last coil removed by peelers	15.64	11.82	27.46	0.10	27.56

Although peeling into limby crowns adds disproportionately to the expense because of the thinner bark and the extra trouble to get it, nevertheless waste could be lessened economically through closer supervision of the peelers.

It is customary to peel all the trees, even down to poles from 3 to 8 inches in diameter. One or two coils are taken from these poles without felling them. This practice, called "jayhawking," also leads to waste in bark. The two coils, which can be taken off without cutting the tree down, do not always include all the bark worth taking. In some districts "jayhawked" trees are frequent with clear trunks for 20 feet above the last coil taken and bark three-quarters of an inch thick. The quality of such waste is shown by the analyses given in Table 4.

TABLE 4.—*Analyses of bark left on "jayhawked" trees, southern Humboldt County.*

Description of tree.	Diameter at 1 foot.	Total height.	Solids soluble in cold water.			Solids soluble in hot water only, reds.	Total solids.
			Tannin.	Non-tannin.	Total.		
1. Two coils taken by peelers; sample from just above second coil	*Inches.* 8	*Feet.* 50	*Per cent.* 13.05	*Per cent.* 6.71	*Per cent.* 19.76	*Per cent.* 0.09	*Per cent.* 19.85
2. One coil taken by peeler; sample from just above coil	3.5	25	13.85	7.15	21.00	.44	21.44
3. Two coils taken by peelers; bark sample from just above second coil	9	55	10.12	6.72	16.84	.....	16.58

TRANSPORTATION.

The bark curls up in three weeks and is then tough enough to stand handling. It is "bunched" or gathered together in small regular piles. The swampers cut narrow sled roads through the woods to the bunches of bark and it is sledded to the wagon road, where it is corded up. In some districts the bark is carried out on mule back, loaded on iron panniers.

After the bark is sledded a woodsman is sent through the woods to sack the chips and search for bark which has been overlooked or

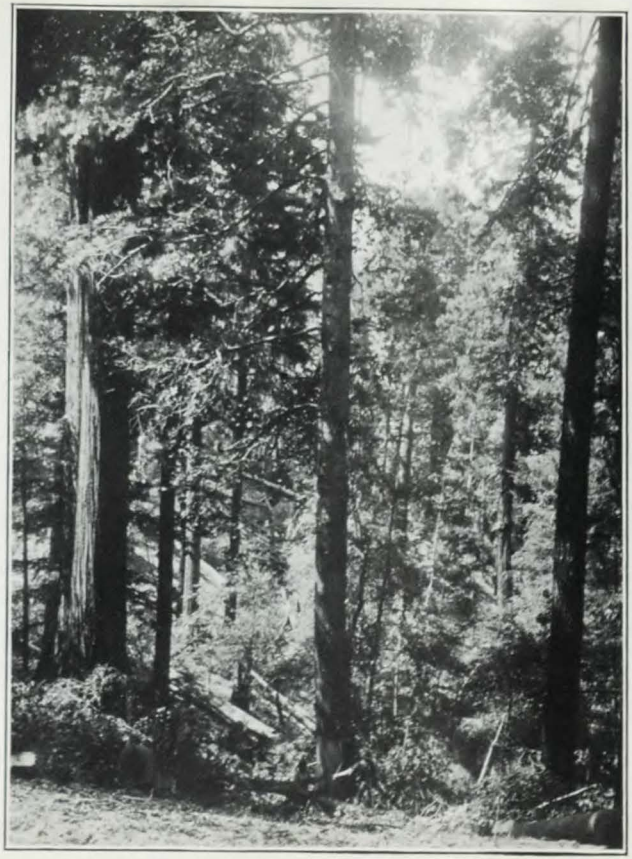


FIG. 1.—TYPICAL TANBARK OAK TREE UNDERGOING REMOVAL OF FIRST RING OF BARK.

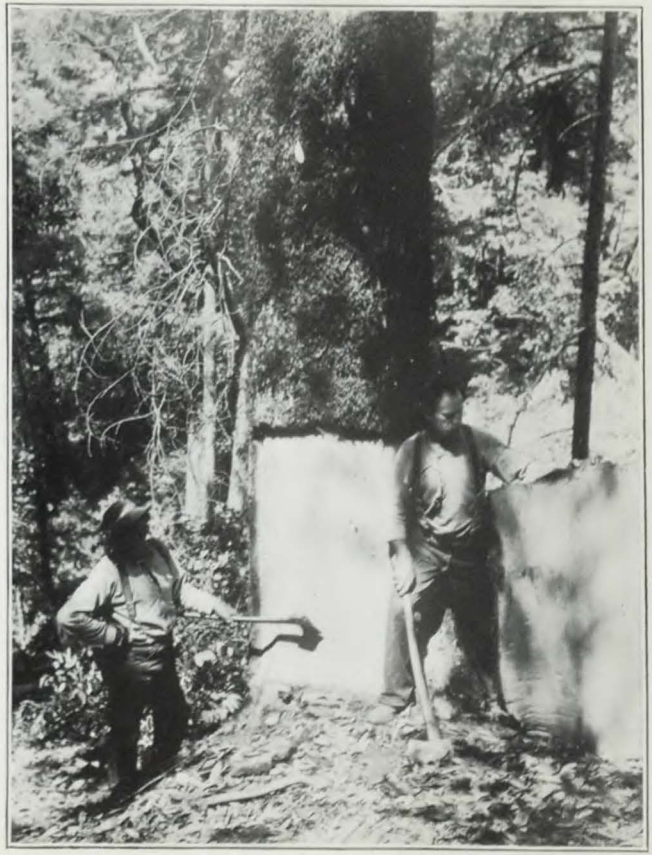


FIG. 2.—CLOSER VIEW OF THE OPERATION.

FIG. 1.—PEELING 4-FOOT RINGS OF BARK FROM THE FELLED TREE.

FIG. 2.—BUNCHING THE BARK IN SMALL PILES ALONG THE SLED ROAD.

FIG. 1.—THE SKIDWAYS TO WHICH THE BUNCHED BARK IS SLEDDED, AND FROM WHICH IT IS HAULED TO THE RAILROAD.

FIG. 2.—HAULING THE BARK IN WAGONS FROM THE SKIDWAYS TO THE CARS.

covered up by the tops of the trees, but even with this precaution, here and there bark piles are left whenever the peelings are extensive. Chipped bark, which comes chiefly from the base or "rump" of the tree, is the richest of all in tannin, and, on account of its greater weight and smaller bulk than coil bark, particularly desirable. But it is much more likely to be scattered and overlooked in the woods, and it would be better woods practice if this bark were piled immediately on peeling and sacked just before the coil bark is bunched. The cost would be no greater than—in all probability not as much as—by the present method. The tannin quality of rump bark is shown in Table 5:

TABLE 5.—*Analyses of the tannin quality of rump bark.*

Locality.	Solids soluble in cold water.			Solids soluble in hot water only, reds.	Total solids.
	Tannin.	Non-tannin.	Total.		
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Southern Humboldt County	29.20	12.86	42.06	2.86	44.92
Santa Cruz County	20.89	6.97	27.86	3.26	31.12

On the Sonoma and Mendocino coasts the tanbark is usually transported to the ocean by the steam logging railways, which follow the courses of the numerous rivers and creeks. These roads were built primarily to carry redwood, but have cars with frames for tanbark. The Mendocino coast is rockbound and there are no real harbors, but only open roadsteads or half-sheltered coves. The cars are run out upon a headland, and the frame, with its load, is lifted by a steam derrick and transported by a cable to a schooner offshore. A schooner that carries 200 cords of bark may be loaded thus in a very short time. Nearly all of the bark shipped by schooner from the Mendocino coast goes to the San Francisco Bay tanneries.

Sometimes tanbark is transported to the coast by four-horse wagons, which have a capacity of from 2 to 4 tons.

The bark delivered for shipment must be air-dry and, according to the rules, must not include any "paper bark" or "snake skin"—that is, bark less than half an inch thick. In practice, however, thin bark is included in the shipments without arousing protest, provided there is not too much of it. In the hot, rainless summers of the Coast Range there is no difficulty in meeting the requirement that the bark be air-dry. Bark rarely reaches the market in less than from four to eight weeks from the time of peeling. Heavy bark loses from 25 to 30 per cent of water in this period, medium bark from 30 to 35 per cent, second growth and paper bark from 35 to 40 per cent. There is also a slight loss, from 0.5 to 1 per cent, due to breakage in handling and shipping.

The long dry season of California is highly favorable to the tanbark industry, since it obviates precaution against rain. Bark held over winter must be sheltered, since more than 25 per cent of tannin is leached out by rain in one winter. Dampness also causes mold, which injures the leather and is difficult to get rid of.

QUALITY OF THE BARK.

The proportion of tannin varies with the part of the tree from which the bark is taken and with the local and geographical situation of the tree. Old bark near the base of the trunk contains the highest proportion. The color of a cross section of fresh bark is an index of the quality in this respect; bark richest in tannin is a deep red, while the poorest is pale or yellowish. Bark is not considered ripe until it has formed three layers, a rougher outer "ross," a central "meat," and an inner "fiber." Before it has divided thus the tannin content is low. Trees in virgin stands arrive at this maturity at from 55 to 70 years of age.

The variation in bark quality on a typical tree is shown in Table 6:

TABLE 6.—*Analyses showing distribution of tannin from the base to the top of the tree.*[1]

Location of sample.	Thickness of bark.	Solids soluble in cold water.			Solids soluble in hot water only, reds.	Total solids.
		Tannin.	Non-tannin.	Total.		
	Inches.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Rump	1 7/8	29.20	12.86	42.06	2.86	44.92
First cut	1 1/4	25.77	12.72	38.49	.....	38.49
15 feet	1 1/8	19.93	10.76	30.69	.....	30.69
31 feet	1 1/8	16.13	9.26	25.39	.....	25.39
45 feet	1	19.37	11.63	31.00	0.16	31.16
60 feet	7/8	13.16	9.40	22.56	.....	22.56
66 feet	7/8	13.21	8.17	21.38	.....	21.38
74 feet	3/4	10.00	6.78	16.78	.....	16.78
78 feet	1/4	12.50	9.42	21.92	.....	21.92
84 feet	1/8	10.82	8.42	19.24	.....	19.24

[1] Tree 18 inches in diameter 4 feet from the ground, and 96 feet high, in northerly hollow, southern Humboldt County.

Sunshine and light increase the secretion of tannin. For this reason the best bark grows on ridges, and the southern districts yield a richer product than the northern. Bark from the Santa Lucia Mountains, the southernmost of all the districts, is the richest in the market and averages as high as from 20 to 24 per cent. According to the tanners who have used bark from widely separated districts, that grown in the "Bald Hills" district in the interior, beyond the influence of the sea fogs, is richer than that from the coast, where the trees are shaded by redwoods and are in the fog belt. Bark from the coast of Oregon is low in tannin, with an average of only 12 or 14 per cent.

Table 7 shows the results of analyses of bark of representative trees of the various districts:

TABLE 7.—*Analyses of bark samples from different districts.*

Bald Hills districts.	Solids soluble in cold water.			Solids soluble in hot water only, reds.	Total solids extract.
	Tannin.	Nontannin.	Total.		
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Thick bark, commercial sample, Briceland, Humboldt County	24.74	13.18	37.92	3.08	41.00
Thick bark, Acorn region, Humboldt County	14.82	9.60	24.42	1.78	26.20
Thin bark, Acorn region, Humboldt County	14.90	11.86	26.76	2.16	28.92
Between Low Gap and Summit, west of Ukiah:					
1½-foot tree, sample at 3 feet from ground, ridge tree	15.60	7.12	22.72	2.52	25.24
1¾-foot tree within 15 feet of preceding	15.36	10.02	25.38	1.88	27.26
Just east of Coast Range summit (west of Ukiah); ridge tree	20.51	11.21	31.72	3.24	34.96
Elk Creek, Mendocino County:					
Thick bark	22.20	11.69	33.89	2.87	36.76
Medium bark	14.92	8.89	23.81	1.15	24.96
Thin bark	14.00	6.73	20.73	1.86	22.59
Ridge tree in open, near coast at Kenny's; 2-foot tree	16.20	8.92	25.12	3.76	28.88
Ridge tree near coast at Kenny's; 2-foot tree	22.73	10.07	33.80	1.14	34.94
South slope tree exposed to sun, Halfway House, Ukiah-Mendocino Road; 2-foot tree	19.08	9.76	28.84	7.96	36.80
San Vicente Creek, Santa Cruz Mountains, Redwood district:					
3-foot smooth-barked tree	21.61	6.85	28.46	2.14	30.60
Rough-barked tree within 10 feet of preceding; 2½-foot tree	18.93	5.40	24.33	2.67	27.00
San Vicente Creek, Santa Cruz Mountains, 3½-foot tree	18.24	9.24	27.48	3.60	30.08

PROLONGING THE SUPPLY.

With the disappearance of the bodies of tanbark oak which have furnished the chief tanning material for the leather manufacturing industry on the Pacific coast the question of the continuation of the supply becomes very important. Since the greater portion of the standing tanbark is now confined to broken and inaccessible mountain country, the extension of transportation facilities to those regions must exert a very marked influence on its exploitation and cost. Railroads and wagon trails are being rapidly pushed into the northern coast ranges, and it is probable that within two or three years the rich belts of Mendocino, Humboldt, and Del Norte Counties will have at least one railway line. The utilization of second growth; the introduction of more conservative methods in the woods, particularly in connection with the redwood lumbering industry; the protection of the forests from fire; and the extension of the use of other products as substitutes for and supplements of the bark of this most important tree, will all have their influences on the future supply.

PROVIDING FOR SECOND GROWTH.

SPROUT REPRODUCTION.

For the maintenance of the supply of tanbark on the Pacific coast the second growth on cut-over areas offers by far the most hope. Sprout reproduction must be encouraged, since the tree sprouts very readily and with great persistence. Sprouts grow from trees of practically any age and under a wide variety of conditions. Of greatest economic significance are those which spring up from the stumps of trees felled for peeling. The sprouts arise from conical woody buds which are formed under the bark at the base of the tree, and which vary in number from a scattering few to crowded thousands. The sprouts themselves vary in number; as many as 1,400 have been counted on one large stump. The practice of peeling the tree down as far as possible, often below ground level, in order to obtain all the rich and heavy rump bark, exposes the buds and prevents sprouts, but peeling can safely be carried down to the surface of the ground if the peelers ring the bottom of the first rim instead of stripping off the bark as far down as it can be torn. The original number of sprouts is reduced by natural processes in 30 years to from four to eight of the most vigorous poles. The rate of height growth is about 2 feet a year. By proper thinning this rate could be accelerated.

Sprouts also come up freely about the base of fire-injured and even fire-killed trees, which is a great advantage where there are frequent forest fires, as in the tanbark oak regions. They even grow vigorously from the stumps of old trees which have been weakened by dry rot or fire and have fallen. The stumps of such fallen veterans may be a yard or two in diameter. Circles of sprouts about the rims of such stumps which have disappeared are often found in the woods, and the trunks of these sprouts are sometimes 2 feet in diameter at 4 feet from the ground. Sometimes sprouts will start from the base of living trees, though this habit is of slight commercial importance.

Nothing can better illustrate the vitality of tanbark oak than the longevity of standing trees which have been peeled. Peeling is usually done before flowering time, and for the first year afterwards the growth of the tree is so decidedly checked that it does not fruit. The second year the tree bears a full crop of acorns—often an excessively large crop. The woodsmen call this the "last kick" of the tree, since in the third year it usually dies. If the tree stands exposed to the full heat of the sun it will probably die the first season. Yet there is abundant testimony that it may continue to live for a long period—even 10 or 15 years. The apparent anomaly of a tree continuing its life functions with a complete band of bark removed from its trunk can be explained by a study of "jayhawked" trees in the field. Such trees were peeled either so early in the season or so late

in the season that the bark did not part readily from the wood, and a very thin portion of the inner bark and cambium layer adhered to the wood and formed a sort of film. This film after one season looks like a thin coat of brown varnish. The wood beneath, however, is greenish and pulpy, suggesting the mesophyll layer of a leaf. This layer does not increase appreciably in thickness.

REPRODUCTION BY SEED.

No other oak on the Pacific coast produces so heavy a crop of acorns as tanbark oak, but seedlings, nevertheless, are not abundant. In the main, forest seedlings are found only where a fallen tree has made a break in the forest canopy and let in light. The "Bald Hills" country is filled with hogs and cattle, which prevent seedling reproduction by devouring the acorns and browsing the tender foliage of the young growth.

Attempts at artificial propagation outside the natural range of tanbark oak have failed. The acorns germinate in open nursery beds in about five weeks. The seedlings come up a little more promptly in loam beds than in adobe, but those in the adobe seem a trifle more vigorous than the others. Sand beds germinate only 2 per cent of the seed.

Eighty per cent of the seeds planted in 1902 at the California Forestry Station at Chico germinated, but not one seedling survived the first summer, although the soil conditions are favorable. The hot, dry climate of the interior valleys does not furnish a normal environment for tanbark oak, and the formation of plantations is practicable only where conditions are similar to those of the natural range of the tree.

SECOND-GROWTH BARK.

For several years second growth has been peeled in the Santa Cruz Mountains, and it is claimed by some owners who superintended both peelings that the yield of second growth exceeds that of the virgin stand. There is nothing to prove or disprove this assertion, but it is probable that these men did not take account of the fact that the harvesting of the crop to-day is very much closer and more careful than the peeling of the virgin timber from 30 to 50 years ago, and that "passed trees" of the virgin stand were stripped at the second peeling. Although it is improbable that the yield of second growth at the end of 30 years would equal that of the original stand, it is sufficiently heavy to make the holding of cut-over lands profitable for repeeling in 30 years, when from 1 to 5 cords per acre can be harvested.

Table 8 gives the yields of a number of second-growth trees in the Santa Cruz Mountains.

TABLE 8.—*Amount of bark on second-growth tan oak, age 29 to 31 years, Santa Cruz Mountains.*

Height of tree.	Diameter of trunk at 2 feet.	Length of peeled trunk.	Diameter of trunk at end of last coil.	Thickness of bark at butt.	Weight of bark, green.	Weight of bark dry (calculated).
Feet.	*Inches.*	*Feet.*	*Inches.*	*Inches.*	*Pounds.*	*Pounds.*
52	7	24	4	1½	145	91
50	6	24	4	1½	143	90
62	10	24	6	1½	241	152
55	7	20	4	1½	125	79
65	9	28	6	2	243	152
55	7	20	5	1¼	120	76
62	8	24	5	1¼	158	100
62	7	24	5	1½	160	101
60	8	28	6	2	235	148
65	10	28	6	1½	303	191
70	9	28	6	1½	303	191
67	10	36	5	2	321	202
68	9	36	5	1¼	241	152
67	9	32	5	1¼	208	131
65	8	32	5	1	177	112

QUALITY OF SECOND-GROWTH BARK.

Tanners estimate that second-growth bark will average only 10 per cent tannin, and when it was first put upon the market they objected to it; but, mixed with virgin bark, it is now used to a considerable extent. It is distinguishable from virgin bark by its peculiar smoothness both on the outside and the inside; by its brittleness, due to lack of fiber, especially toward the inside, where virgin bark is so fibrous; and by its sappiness and light color.

Table 9 shows the characteristics of samples taken from near the bases of trees. The thinner bark higher up would, of course, lower the average.

It is possible to produce a good quality of leather by the use of second-growth bark alone, but a large quantity is required to offset its low tannin content. The item of labor is also greater, since it costs more to handle the extra bark.

TABLE 9.—*Analyses showing tannin content of tan-oak bark taken from three second-growth trees.*

Locality.	Height.	Diameter of wood at 1 foot.	Age.	Solids soluble in cold water.			Solids soluble in hot water only, reds.	Total solids.
				Tannin.	Nontannin.	Total.		
Between Comptche and Low Gap, one of 16 sprouts about stump	*Feet.* 14½	*Inches.* 2½	*Years.* 7	*Per cent.* 18.28	*Per cent.* 8.28	*Per cent.* 26.56	*Per cent.* 1.00	*Per cent.* 27.56
Between Comptche and Low Gap	40	5	24	16.22	10.60	26.82	.56	27.38
San Vicente Creek, Santa Cruz Mountains	60	9	30	14.10	8.94	23.04	.52	23.56

CONSERVATIVE METHODS IN THE WOODS.

Redwood lumbering has done much to keep the annual supply of tanbark steady and to make remote stands accessible. It is the practice of the redwood lumber companies to send tanbark crews through the woods in advance of the redwood logging crews, since the firing of the district, which always follows felling, to facilitate the getting out of the redwood logs by wire cable and donkey engine, badly injures all standing trees, and even if it does not actually destroy the tanbark oak it makes peeling difficult or impossible.

GUARDING AGAINST FIRE.

Up to the present time no attention has been paid to the future condition of the forest in which peeling has been carried on. Yet the introduction of conservative methods would prevent a very large waste. Fire, which always accompanies redwood logging, makes it an economical policy to take all the bark possible, whether the tree has reached maturity or not. Under conservative methods "jayhawked" trees, which yield only from 10 to 60 pounds of bark with a low tannin content, would in 10 or 20 years form profitable elements in the new stand for both bark and wood. Despite the custom of taking all the bark that can be peeled without regard to whether it is mature or not, the maximum yield is never obtained under present methods. Some trees which will not for one reason or another peel readily in one season, although they would a year or two later, are sacrificed in order to chip a little bark off their trunks or to secure one or more coils because the trees are considered as doomed to fire anyway. Often from 70 to 90 per cent of the bark in such cases can not be taken from the tree. Moreover, the fires kill very young trees, kill sprouts down to the stumps, and seriously interfere with reproduction. Under conservative management the older trees would be saved for peeling in a favorable year and the younger ones permitted to develop a new stand. As tanbark oak always grows in mixed stands, the holding of redwood and Douglas fir lands for a second crop would give the tanbark oak the necessary fire protection and would furnish a profitable element in the later harvests.

During the rainless season in California, from May to October, even in the foggy coast region, fires caused by logging crews, hunters, campers, and in the far north coast ranges by thunderstorms, lead to several million dollars damage every year. These fires rarely kill tanbark oak trees, but make long vertical wounds from 4 to 10 feet up the sides of the trunks. On young trees these injuries are often completely covered by the meeting of new bark growth, but with trees more than 100 years old the sides of the wound usually spread. The exposed wood rots, and such trees, called "goose pens," are difficult

to lay out accurately in felling. Even a slight injury to the trunk permits the entrance of fungi which weaken the wood, and the loss of such trees in heavy snowfalls is very large.

Trees on slopes or canyon sides are the greatest sufferers; 95 per cent of the tanbark oak trees in those positions are injured by fire and 80 per cent fire hollowed. In the case of ridge trees, about 80 per cent are comparatively free from fire hollows, because a fire traveling up a slope is either running high or going out when it reaches the top.

The most extensive destruction by fire in the tanbark oak belt has probably been in Del Norte County, where in former days the Indians regularly fired the woods to make better feed for the deer, and the packers set fires to keep the trails open. Ridge after ridge has been wholly or partly reduced to a low chaparral growth, although there is evidence that a dense forest existed at a comparatively recent date. A conservative estimate of the loss of tanbark by fire within 15 years in this region is 60,000 cords.

In the second-growth districts the accumulation of débris inside the circles of poles about the remains of the parent stumps furnishes material for flames. Forty per cent of such poles show serious injury at the bases.

TANNIN EXTRACT PROCESSES.

The difficulty of transportation has prevented the exploitation of some of the most productive tanbark oak regions in Humboldt and, to a smaller extent, in Mendocino County. An attempt was made to reduce this difficulty by grinding up the bark and shipping it in sacks, but this did not help in the more remote districts where the weight was the chief drawback. In the last few years attempts have been made to solve this difficulty by extracting the tannin from the bark and shipping the extract.

Two methods have been tried in California, the open-pan process and the vacuum-pan process. The open-pan process was tried in southern Mendocino County in 1900 and 1902, but was abandoned because the heat necessary to secure rapid evaporation in concentrating the mixture of ground bark and liquid was said to scorch the fluid and start fermentation, so that the barrels containing the completed product often burst.

The vacuum-pan process is used by an extract plant at Briceland, Humboldt County. The liquid from the leaching vats is pumped into settling tanks in the concentrator house, and thence fed as needed into the "pan" or evaporator, which is a copper retort about 7 feet in diameter, heated by steam pipes coiled around the base. By heating the pan under vacuum the temperature of the liquid during evaporation is kept from exceeding about 120° or 130° F.

The vapor is condensed in a receptacle high enough above the pan to permit a 34-foot vertical waste pipe. This pipe, kept full of water, supplies a water column sufficient to offset the atmospheric pressure and maintain the vacuum.

A cord of dry bark, 2,200 pounds, is reduced to 50 gallons of extract, which weighs about 550 pounds. The extractor has a capacity of 12 cords a day.

SUPPLEMENTAL MATERIALS.

The duration of the bark supply from tanbark oak will be extended somewhat by the use of other materials as supplements or substitutes. The superiority of the product of the tanbark oak over all other Pacific coast barks is due not altogether to its high percentage of tannin, but rather to the quality of the particular tannin contained in it, and perhaps also to the presence of certain other acids, such as gallic and acetic. The value of this combination is proved by tanning experience. Mixing imported tanning materials, such as gambier and quebracho, increases its effectiveness and counteracts some of its undesirable qualities. As tanners have learned the use and value of these supplementary agents, methods have been more and more adapted to them, until to-day they are regarded as indispensable and the tanbark oak product is never used alone.

As the accessible supply of tanbark oak grows scarcer and dearer, the bark from other species of oak is occasionally mixed with the superior material. This is especially the case in the southern districts, where the tanbark oak is more nearly exhausted. The barks of the California black oak and the coast live oak run so high in tannin that if tannin content alone were an index of tannage value they could compete with tanbark oak. They can not be used alone, because they will not produce leather of good quality; the live-oak bark in particular imparts a gritty character to the leather, which ruins the knives of the cutters, but mixed in moderate quantities with the better bark they make possible a considerable saving.

Alder bark is occasionally found in shipments of bark from tanbark oak, but the tree does not grow in sufficient quantity in California to be a factor in bark supply. In the Mendocino woods the chinquapin is often peeled, but it contains so little tannin that it is practically worthless. Moreover, it is very fibrous and tough, which makes it difficult for the smaller tanbark mills to handle.

Analyses of average bark samples from the main trunks of the important California trees are given in Table 10. Some of these have never been subjected to commercial experiment.

TABLE 10.—*Tannin analyses of bark of the more important forest trees of the Pacific coast.*

Species.	Locality.	Soluble solids.			Insoluble solids, reds.	Total solids.
		Tannin.	Nontannin.	Total.		
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
California black oak (*Quercus californica*).	Vaca Mountains, Solano County.	10.00	10.25	20.25	0.95	21.20
California black oak	Briceland, Humboldt County.	10.16	7.88	18.04	.32	18.36
California live oak (*Quercus agrifolia*).	Berkeley	18.76	9.40	28.16	1.48	29.64
Highland oak (*Quercus wislizeni*).	Vaca Mountains, Solano County.	7.92	5.88	13.80	1.20	15.00
Highland oak	Southern Mendocino	6.67	2.83	9.50	1.64	11.14
Canyon live oak, maul oak (*Quercus chrysolepis*).	Vaca Mountains, Solano County.	12.18	10.18	22.36	.80	23.16
Canyon live oak	South central Mendocino.	6.56	5.19	11.66	1.00	12.66
California white oak (*Quercus lobata*).	Visalia	11.97	11.28	23.25	1.55	24.80
Pacific post oak (*Quercus garryana*).	Southern Humboldt	7.07	4.93	12.00	.36	12.36
Pacific post oak	South central Mendocino, "Bald Hills."	6.20	4.16	10.36	1.00	11.36
Western chinquapin (*Castanopsis chrysophylla*).	Southern Humboldt	7.60	4.34	11.94	.64	12.58
Red alder (*Alnus oregona*)	Mendocino coast	8.60	12.00	20.60	1.68	22.28
California yellow willow; western black willow (*Salix lasiandra*).	Berkeley	1.45	3.09	4.54	.00	4.54
California laurel (*Umbellularia californica*).	Briceland	15.58	10.46	26.04	.97	27.01
Monterey pine (*Pinus radiata*).	Berkeley (cult.)	14.11	2.85	16.96	2.60	19.56
California swamp pine (*Pinus muricata*).	Mendocino coast	13.45	3.99	17.44	3.72	21.16
Lowland fir (*Abies grandis*)	do	9.03	4.59	13.62	.74	14.36
Sitka spruce (*Picea sitchensis*).	do	17.52	6.24	23.76	1.60	25.36
Douglas fir (*Pseudotsuga taxifolia*).	Southern Humboldt	7.15	5.25	12.40	.42	12.82
Western hemlock (*Tsuga heterophylla*).	Mendocino coast	10.80	3.46	14.26	1.32	15.58
Western hemlock	Noyo River, Mendocino coast.	14.40	6.56	20.96	2.42	23.38
Redwood (*Sequoia sempervirens*) bark.	Mendocino coast	2.50	2.74	5.24	.10	5.34
Redwood, sapwood	do	1.76	5.72	6.48	.59	7.07
Redwood, heartwood	do	3.91	5.85	7.76	1.58	9.34

POSSIBILITIES OF UTILIZING THE WOOD.

The tanbark oak peeled since 1850 is equal to more than 2,000,000 cords of firewood. But, chiefly on account of the difficulty of transportation, little of this amount, perhaps 5 per cent, has been used as fuel. Yet the wood has such particular value for special purposes that it is quoted in San Francisco at from $12 to $18 per cord, a price much higher than that of any other California oak. The wood burns up very completely with little smoke. The United States mint at San Francisco uses it, and there is a steady demand by the bakers of that city. The full possibilities of the wood for lumber can be determined only by experiments in sawing and seasoning and by strength tests, but its availability for some purposes is undoubted. About 400,000,000 feet have been utterly lost so far, and about 627,000,000 feet are still standing. To utilize the log for lumber, it must be cared for immediately after peeling. Only the redwood logging companies possess facilities for yarding and sawing the tanbark oak; yet since the peeling time comes at the height of their busy season, any proposal

to depart from the custom of abandoning the tanbark oak log as useless does not meet with favor. Moreover, their milling machinery is not well adapted to sawing oak logs, and, for satisfactory work, the installation of special plants would be necessary.

Country wagon makers in the Coast Range constantly use tanbark oak for repair work and believe it superior to all other wood for felloes.

The wood, unlike some others, such as the eastern chestnut, has no value whatever as a tanning agent.

CONCLUSIONS.

(1) The bark of tanbark oak is one of the most valuable tanning agents known for the production of heavy leather. Bark from the interior ridges and southern districts is prized more than bark from the deep redwood belt or from northern districts, because it averages higher in tannin.

(2) The Pacific coast tanbark-oak belt contains enough standing tanbark at the present time to supply the needs of California tanneries at their present rate of consumption for 47 years.

(3) There should be more systematic methods in peeling and a greater proportion of the bark above the clear trunk should be taken. Bark from one-half to one-fourth inch thick should be saved whenever possible. Chipped bark should be sacked before bunching the coil bark. Trees with bound bark should be temporarily passed, and not mutilated or sacrificed. Tops should be burned in the winter following cutting to prevent the destruction of young growth and of passed trees by wild forest fires.

(4) Tanbark oak is surpassed in reproductive powers by no other forest trees in western America, except the redwood, and it stands very close to that species. A crop of sprouts will normally arise from the base of every peeled stump. In order to favor this crop, peelers should ring the trunk at base and not break the coil down below the surface of the ground. These sprouts will give rise to "second-growth" poles which are commercailly profitable to peel within 25 or 35 years.

(5) Standing trees after being peeled may live on indefinitely, but they never produce a second bark which has any commercial value.

(6) The wood is, for the most part, allowed to rot on the ground. Prompt care would tend to obviate its greatest weakness, checking in seasoning, and it can certainly be applied to some of the uses for which oak wood is prized, and a stupendous annual waste thereby be eliminated.

(7) Forest fires are a source of great annual loss, and cooperative measures should be taken by the State of California, the coast counties, the redwood companies, the tanbark companies, and cattle-range owners to reduce the danger from fire. A conservative treatment of the redwoods to obtain a continuous crop will be of like advantage to the tanbark oak mixed with it.

PART II.—UTILIZATION OF THE WOOD OF TANBARK OAK.

By H. S. Betts.

TANBARK-OAK LUMBER.

While the wood of tanbark oak is sometimes used for fuel, it is more generally burned in the redwood logging operations, or left to rot in the woods. The object of this study is to bring to the attention of west coast hardwood users and the owners of tanbark-oak stumpage the possibility of using tanbark-oak lumber.

The largest part of the hardwoods used on the Pacific coast is imported from the eastern part of the United States. From 1899 to 1906 there was an increase in the price of hardwoods in the East of from 25 to 65 per cent. These conditions have been reflected in the western hardwood markets. Not only are the prices of most kinds of hardwood going up rapidly, but in some cases certain species are difficult to obtain at any price. This scarcity is due not to any local condition, but to the general shortage of hardwood timber. The high price is due to the eastern market price, to which must be added about 85 cents per hundredweight in freight charges, or an advance of from $24 to $36 or even $40 per thousand board feet.

Yet tanbark oak furnishes a fair quantity of good material. For instance, the average yield of bark is from 1¼ to 2⅛ cords per acre. If, as seems reasonable, there are 800 feet board measure of lumber for every cord of bark, the yield in lumber would be from 1,000 to 1,760 feet board measure per acre. Exceptionally fine stands yield as high as 8 cords of bark to the acre, which would mean 6,400 board feet of lumber.

APPEARANCE AND CHARACTERISTICS OF THE WOOD.

The wood of tanbark oak, like that of other oaks, is porous and has the characteristic strongly marked medullary rays. In color it is light brown, faintly tinged with red. When the wood is first cut the sapwood is somewhat lighter in color than the heartwood, but after a few weeks' exposure to the air the two become very similar in appearance.

Exact knowledge of the rate of growth of tanbark oak is very limited. Seven forest-grown trees near Sherwood, Cal., showed variations of from 10 to 20 rings per inch. The trees were from 14 to 27 inches in diameter 2 feet above the ground. Even on the stump the

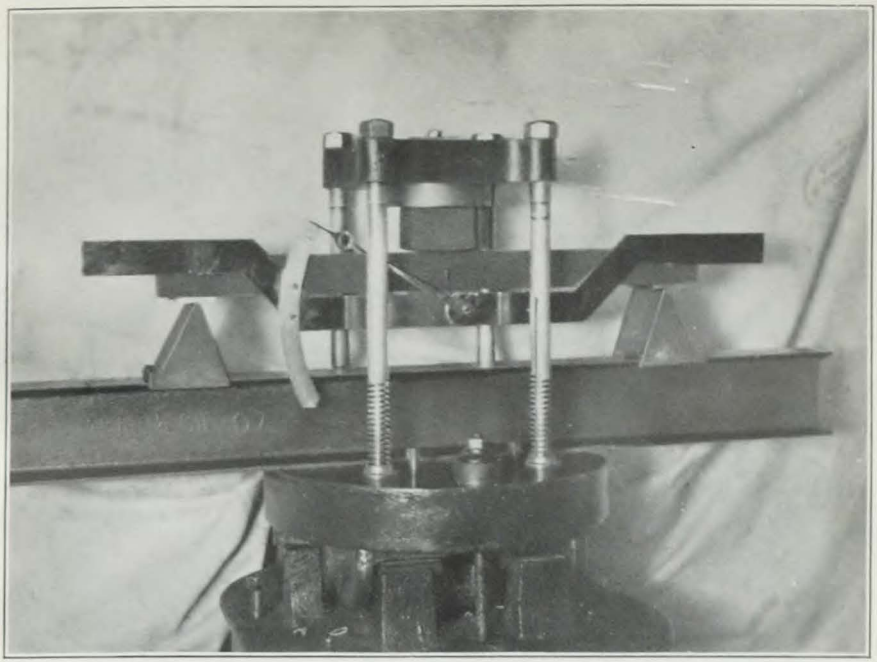


FIG. 1.—MACHINE AND METHOD USED FOR TESTING SMALL BEAMS.

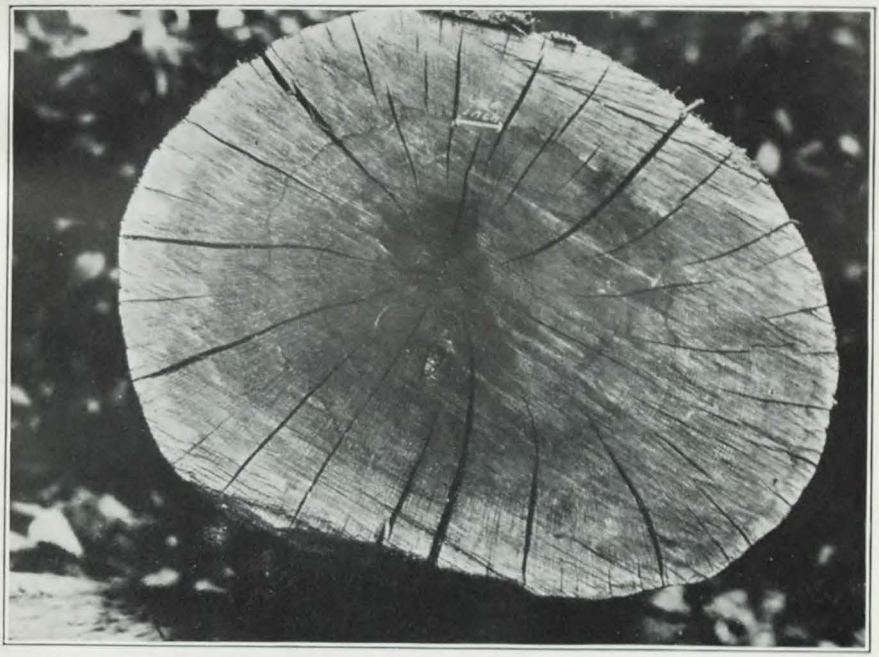


FIG. 2.—SEASONING CHECKS IN THE BUTT OF A TANBARK OAK LOG THAT HAS BEEN SUBJECTED TO THE SEVERE TEST OF BEING TURNED UP AND EXPOSED TO THE HOT CALIFORNIA SUN FOR SIX WEEKS.

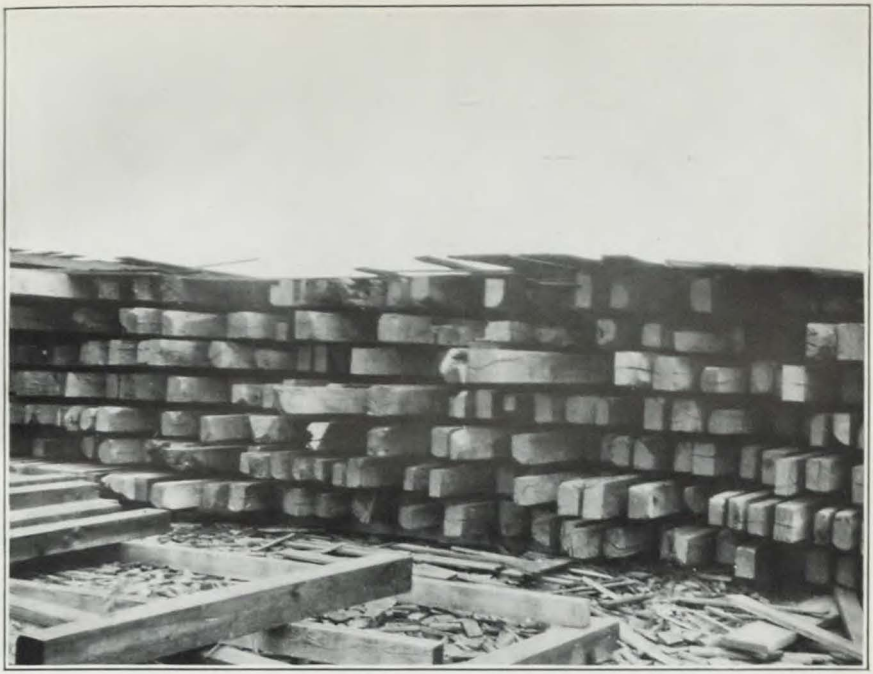


FIG. 1.—TANBARK OAK LUMBER FOR CAR CONSTRUCTION.

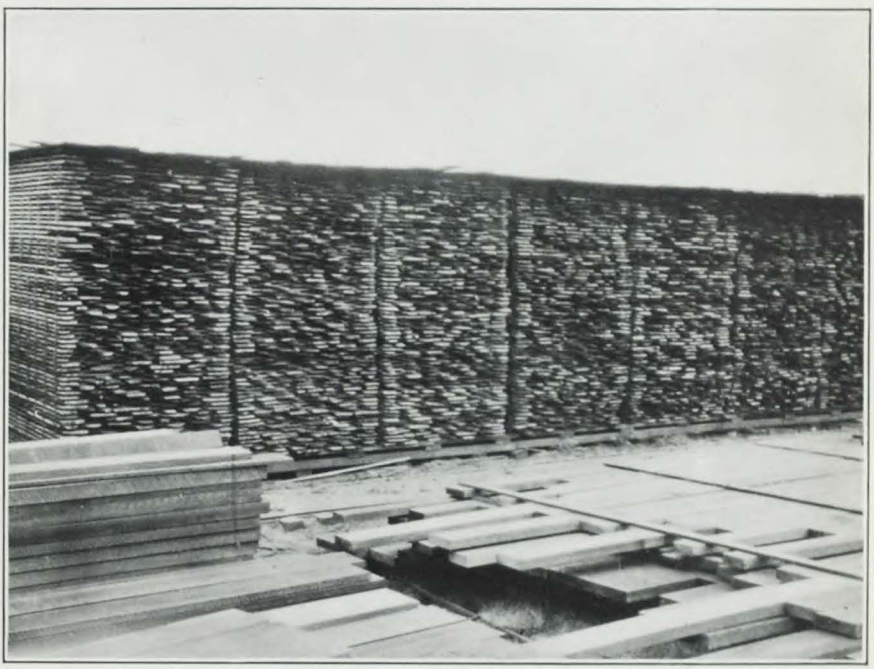


FIG. 2.—TANBARK OAK BOARDS AIR DRYING.

annual rings are difficult to distinguish, since the temperature changes from season to season are not marked enough to form the distinct bands of spring and summer wood common in eastern oaks. In the case of the lumber, it becomes impracticable to attempt to obtain the rate of growth of different pieces.

STRENGTH.

The material used in the tanbark oak tests was divided into three classes or shipments, differing in the age of the trees and the season of cutting. The first two shipments were selected in the summer during the peeling season, and represented in the first shipment the larger and more mature trees of the stand, and in the second shipment the smaller and younger trees. The third shipment was felled in October and represented the same wood as that obtained in the first shipment, but felled in the season when the bark was tight, or when the sap was not running.

The strength of the wood in several conditions of seasoning is shown in Table 11. The three shipments had practically the same strength and, therefore, were combined in the table.

TABLE 11.—*Strength of small clear pieces of tanbark oak, green, air-dry, and kiln-dry, size 2 by 2 inches in section.*

GREEN.

	Bending.							
	Number of tests.	Moisture content.	Weight per cubic foot.		Fiber stress at elastic limit per square inch.	Modulus of rupture per square inch.	Modulus of elasticity per square inch.	Elastic resilience per cubic inch.
			As tested.	Oven dry.[1]				
		Per ct.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*1,000 pounds.*	*Inch pounds.*
Average	256	89.5	66.5	43.1	6,576	10,707	1,678	1.49
High 10 per cent	26	110.5	71.7	48.1	8,283	12,880	2,251	2.35
Low 10 per cent	26	65.5	60.3	38.2	4,869	8,632	1,203	.83
AIR-DRY (10 TO 20 PER CENT MOISTURE).								
Average	567	14.0	45.2	43.2	9,080	15,512	2,083	2.27
High 10 per cent	57	17.4	51.7	50.5	11,901	20,342	2,771	3.45
Low 10 per cent	57	10.5	39.5	37.1	6,482	11,625	1,511	1.19
KILN-DRY (5 TO 10 PER CENT MOISTURE).								
Average	31	9.6	45.4	43.9	9,289	17,693	2,292	2.17
High 10 per cent	3	10.0	50.2	48.8	12,287	22,417	2,966	3.41
Low 10 per cent	3	8.8	40.9	39.5	6,600	13,077	1,642	1.11

TABLE 11.—*Strength of small clear pieces of tanbark oak, green, air-dry, and kiln-dry, size 2 by 2 inches in section*—Continued.

GREEN.

	Compression parallel to grain.			Compression perpendicular to grain.			Shearing.		
	Number of tests.	Moisture content.	Crushing strength per square inch.	Number of tests.	Moisture content.	Strength at elastic limit, per square inch.	Number of tests.	Moisture content.	Strength parallel to grain per square inch.
		Per ct.	*Pounds.*		*Per ct.*	*Pounds.*		*Per ct.*	*Pounds.*
Average	237	86.8	4,845	244	77.9	1,355	221	83.1	1,414
High 10 per cent	24	105.4	5,819	24	95.3	1,964	22	103..	1,685
Low 10 per cent	24	64.8	3,711	24	59.7	926	22	56.1	1,075
AIR-DRY (10 TO 20 PER CENT MOISTURE).									
Average	406	14.4	8,172	316	13.4	1,656	204	13.3	1,960
High 10 per cent	41	17.7	10,405	32	16.9	2,343	20	16.9	2,402
Low 10 per cent	41	10.7	6,265	32	10.5	1,238	20	10.6	1,585
KILN-DRY (5 TO 10 PER CENT MOISTURE).									
Average	28	9.4	9,398	26	9.5	1,818	22	9.0	2,037
High 10 per cent	3	10.0	10,737	3	10.0	2,293	2	10.0	2,384
Low 10 per cent	3	8.2	8,047	3	8.4	1,366	2	7.3	1,669

[1] The values in this column are based on a shrinkage of 18 per cent volume. The fiber saturation point is taken as 30 per cent moisture.

Clear, straight-grained specimens free from defects are needed in determining the strength of the wood itself. The results of tests made on this class material can also be used for comparison with similar tests on other kinds of wood. Pieces 2 by 2 inches in section have been found well suited to tests of this kind. For bending,[1] they are cut about 30 inches long, and for compression parallel to the grain and compression perpendicular to the grain, from 6 to 10 inches long. The blocks for shear parallel to the grain are cut with a projecting lip that is sheared off under test. In making a bending test the beam is supported at the ends and loaded at the middle. The supports for the beam are on the weighing platform of the testing machine, so that the load on the beam can be determined at any time during the test. This load is applied by a crosshead which can be forced down on the test specimen by means of heavy screws turned by a train of gears. The deflection or bending of the beam is measured by an apparatus (Pl. VIII, fig. 1) consisting of a light steel frame on which is mounted a movable pointer. In making a test, the frame is rested on two nails driven into the beam near the ends and the pointer attached to the center of the beam in such a way

[1] For a detailed description of methods used in the tests, see Forest Service Circular 38 (revised), Instructions to Engineers of Timber Tests.

that it moves over a graduated arc when the beam bends, and thus shows the amount of bending.

The test is begun by loading the beam with about one-twentieth of the probable breaking load and noting the deflection. The load is then increased by a certain increment which is recorded with the corresponding deflection, and the process continued until the beam breaks. The results of tests on beams of various sizes are reduced to a unit basis, so that direct comparisons as to strength and stiffness can be made between pieces of different sizes of the same or of different species of wood.

In computing the results, the breaking strength is represented by "modulus of rupture," the stiffness by "modulus of elasticity," the load the material will carry without taking a set by "fiber stress at the elastic limit," and the ability to withstand shock without taking a set by "elastic resilience."

Tests in compression parallel with the grain are made by crushing the specimens endwise as they stand upright on the platform of the testing machine. In the case of compression perpendicular to the grain, the tests are made by placing a piece of metal 2 inches wide across the test specimen as it lies flat on the platform of the machine and pressing the piece of metal against the block of wood by means of the crosshead of the machine. This test is carried only slightly beyond the elastic limit of the wood under test, as loading beyond that point has at present no significance. The action is similar to that of a rail on a tie.

In making a shearing test the block is clamped firmly in a frame with the lip projecting. The frame is placed on the platform of the machine and the lip sheared off by means of a sliding plate applied against the upper surface of the lip and parallel to the grain.

Table 11 shows the oven-dry weight of tanbark oak to be about 43.2 pounds per cubic foot. Air-dry tanbark oak, containing 15 per cent moisture, weighs about 50 pounds per cubic foot, or 4,160 pounds per 1,000 board feet. This weight is about the same as that of white oak and is somewhat higher than that of red oak.

The average bending strength (modulus of rupture) of green tanbark oak is 10,707 pounds per square inch, and the average crushing strength, 4,845 pounds per square inch. The results of similar tests on several kinds of hickory by the Forest Service, including pignut, shagbark, mockernut, big shellbark, nutmeg, and water hickory show a bending strength of from 9,200 pounds per square inch for green nutmeg hickory to 11,450 pounds per square inch for green pignut hickory. The average oven-dry weight of pignut hickory is about 51 pounds per cubic foot.

Such tests as have been made on eastern white and red oaks indicate that tanbark oak in bending and crushing strength ranks about the same as white oak and is somewhat superior to red oak.

Data are not available for a comparison of the toughness and stiffness of tanbark oak and the eastern oaks and hickories.

Table 11 shows a considerable increase in the strength values of the air-dry material over the green, and a still further increase in these values for the kiln-dry material.

In compression perpendicular to the grain, green tanbark oak has an average strength at the elastic limit of 1,355 pounds per square inch. Green Douglas fir has an average strength of 651 pounds per square inch.

In shearing strength air-dry tanbark oak shows an average of 1,960 pounds per square inch. Douglas fir has an average shearing strength of 770 pounds per square inch for air-dry pieces.

Douglas fir would, of course, be expected to have lower strength values than a hardwood like tanbark oak. The comparison is used because such tests on other hardwoods have not yet been made.

SEASONING.

A number of the logs selected for testing purposes were sawed into boards for a seasoning test. Fifty 1-inch boards were put through a commercial dry kiln of the moist-air type in San Francisco. The results, while encouraging as regards the behavior of tanbark-oak lumber in a moist-air kiln, were not satisfactory, owing to the imperfect regulation of the kiln and consequent daily variations in temperature and humidity. After 40 days in the kiln a classification of the lumber gave the following:

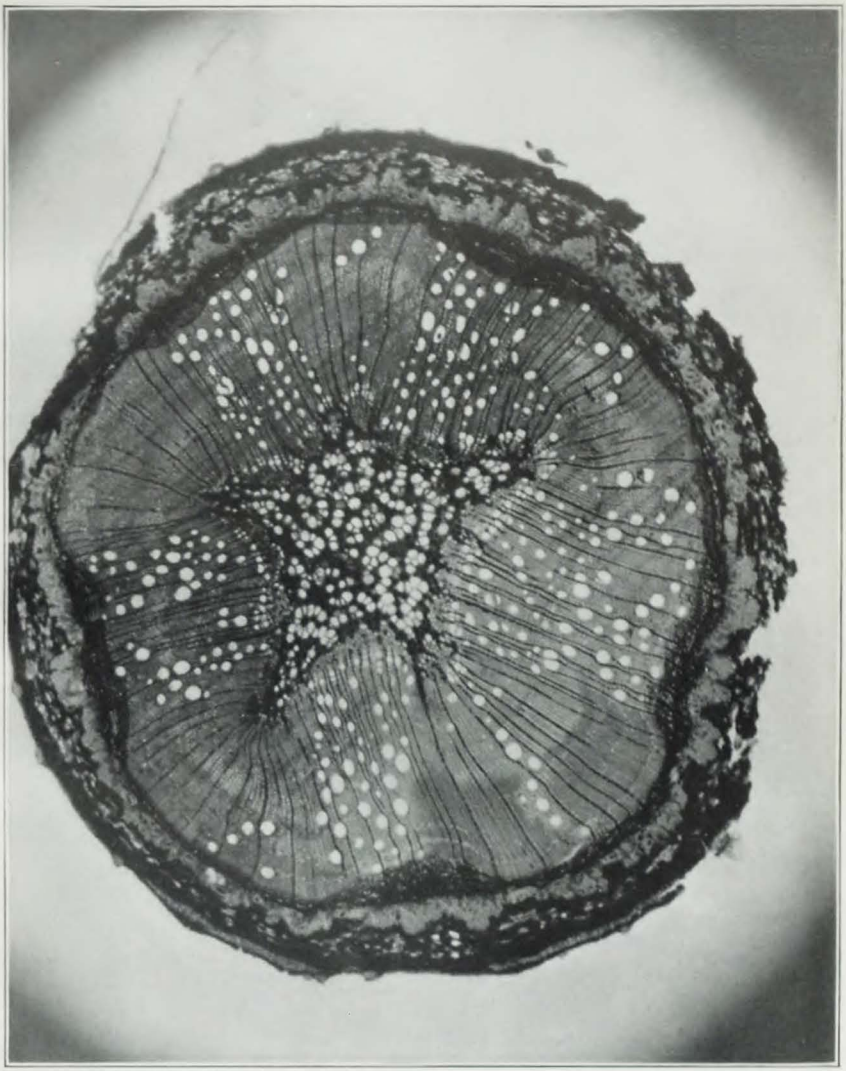
	Number.	Per cent.
Good boards	28	56
Boards slightly warped	12	24
Boards checked at ends	4	8
Boards badly checked	6	12

The average temperature of the kiln was only 85° F. for the 40 days, whereas it should have been at least 110° F. The loss in seasoning eastern oak for vehicle stock is placed at about 10 per cent.

The method of seasoning used by a lumber company which owns considerable tanbark-oak stumpage that it is preparing to put on the market in the form of flooring is as follows: The logs as soon as convenient after they come in from the woods are cut into $1\frac{1}{8}$-inch material. This is then carefully piled in the open yard, with sticks every 18 inches, and allowed to dry from 3 to 6 months. It is finally kiln dried from 30 to 40 days at a temperature not to exceed 110° F., when the boards are ready to be made into flooring. The kiln used is of the blower type. The results obtained in drying tanbark oak by this method have been very satisfactory. It should be remembered that the trees in this case were cut during the peeling season (May to

FIG. 1.—TANBARK OAK FLOORING, AND THE METHOD OF STORING AND SORTING IT.

FIG. 2.—TANBARK OAK FLOORING READY FOR SHIPMENT FROM THE MILL.



TRANSVERSE SECTION OF A 2-YEAR-OLD TWIG OF TANBARK OAK, SHOWING TANNIN (DARK STREAKS AND AREAS) IN THE PITH, PITH RAYS, AND BARK. MAGNIFIED 30 DIAMETERS.

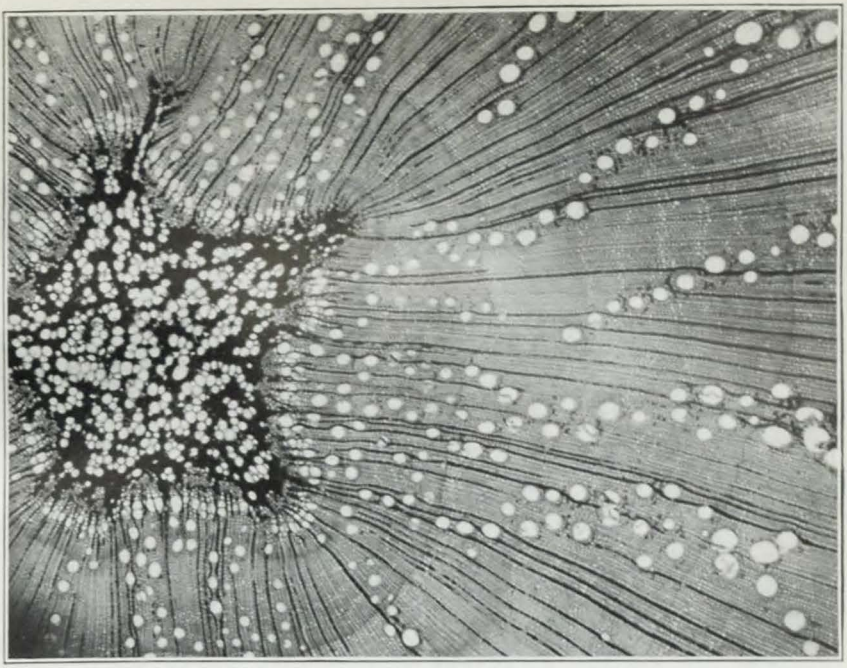


FIG. 1.—TRANSVERSE SECTION OF A 3-YEAR-OLD TWIG OF TANBARK OAK, SHOWING THE DISTRIBUTION OF TANNIN IN THE PITH AND PITH RAYS. MAGNIFIED 30 DIAMETERS.

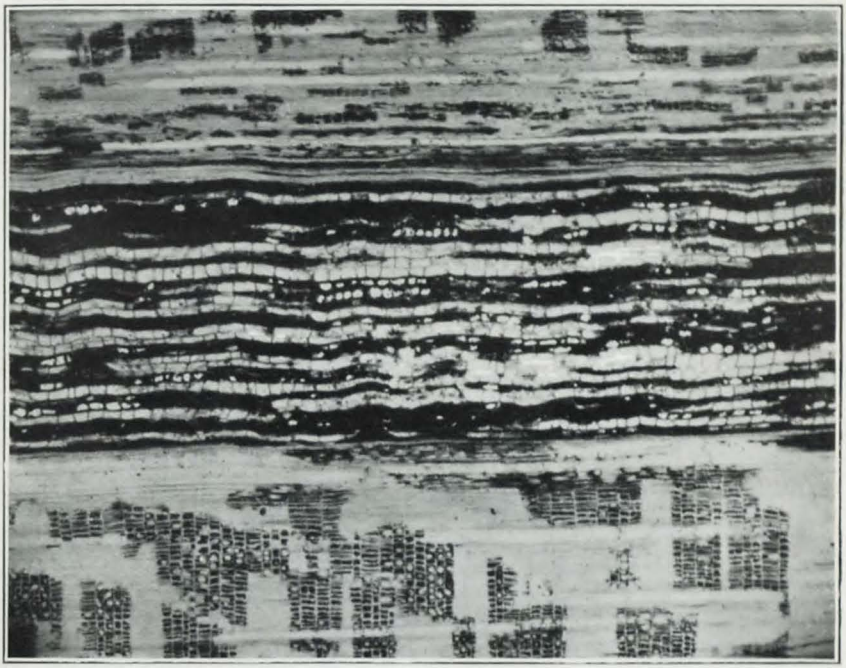


FIG. 2.—LONGITUDINAL RADIAL SECTION OF A 3-YEAR-OLD TWIG OF TANBARK OAK, SHOWING THE TANNIN IN THE PITH AND PITH RAY CELLS. MAGNIFIED 30 DIAMETERS.

October). It is very probable that winter-cut lumber could be seasoned with less loss of material.

Some of the boards and planks sawed from the logs selected for testing were piled under shelter and seasoned for about two years, when they were in the same condition as regards warping and checking as is usually found in eastern oaks similarly handled. Some of the lumber showed a tendency to a "blue rot," apparently caused by too close piling, since this defect was remedied by a wider piling that gave more circulation of air.

In the case of some 200 pieces for mechanical tests (2 by 2 by 30 inches), cut from material seasoned under shelter for two years and then kiln dried, the pieces showed practically no checking. The sides of the pieces were slightly depressed in a few instances, but on the whole their condition was excellent.

All things considered, the seasoning of tanbark oak seems to offer little, if any, more difficulty than is experienced with eastern oaks.

SHRINKAGE.

In order to determine the amount of shrinkage in tanbark oak, 62 pieces (2 by 2 by 10 inches) were dried out slowly from a green to an oven-dry condition. The pieces were selected so that two sides were tangential to the annual rings. They were weighed and measured at intervals for a period of about one year. The drying was carried on first in a warm room and finally in an oven.

When a piece of green or wet wood is dried, no change in dimensions takes place until a point called the fiber-saturation point[1] (generally in the neighborhood of 30 per cent moisture) is passed. The wood then begins to shrink in cross-sectional area and continues to do so uniformly with the removal of moisture until it is bone dry. The longitudinal shrinkage is so small as to be negligible. Generally, the heaviest wood shrinks the most and sapwood shrinks more than heartwood of the same specific gravity. Shrinkage is greater in the circumferential than in the radial direction.

The results of the shrinkage tests on tanbark oak showed an average shrinkage in volume of 18 per cent[2] when the pieces were dried from a green to an oven-dry condition. Of this amount about 6 per cent is radial shrinkage and about 12 per cent tangential. Air-dry wood generally contains about 15 per cent moisture, so that the shrinkage from the green to the air-dry state is only about half that from the green to the absolutely dry state.

The average shrinkage in volume with red oak when dried from a green to an oven-dry state is about the same as with tanbark oak. Both woods vary considerably.

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[1] For a full discussion of the fiber-saturation point, see Forest Service Circular 108, The Strength of Wood as Influenced by Moisture, by H. D. Tiemann.

[2] This figure is based on dry volume.

HARDWOODS USED ON THE COAST.

The hardwoods at present used in the Pacific coast States come from many foreign markets, and only a very small proportion of them are local woods. From the Eastern States are imported oak, ash, hickory, maple, cherry, basswood, black walnut, tulip poplar, birch, and elm; from Honduras, mahogany; from Mexico, Mexican mahogany, prima vera, or jenizero; from Hawaii, koa; from Australia, iron bark (one of the eucalypts) and red bean; and from Japan, Siberian oak.

The hardwoods from the Eastern States come for factory use in the rough or "club" form; for the vehicle industry as roughly finished parts, such as spokes, hubs, bent rims, and sawed felloes; and for cooperage as rough staves and heading. The rest are in the form of 1-inch and 2-inch boards and 3 to 6 inch planks from 6 to 16 inches wide and from 10 to 30 feet long. A small proportion comes in the form of squared timbers up to 20 by 20 inches by 24 feet long. This is for special-order work. The Mexican, Australian, Hawaiian, and Japanese woods generally come in the shape of roughly hewn timbers, the sizes ranging from 14 by 14 inches up to 36 by 36 inches and from 10 to 20 feet long. These rough timbers are sawed into veneer stock, boards, and planks, as wanted.

Eastern oak makes up by far the largest amount of hardwood used in California, with hickory next, followed by maple, ash, and cottonwood.

Some of the hardwoods have a variety of uses, while others are confined to special lines. Of the eastern woods, ash, maple, hickory, elm, and birch are used chiefly for wagon stock, only a small part being used as lumber. Oak is largely used for cooperage, lumber, and wagon stock, in the order named. The term "lumber" includes boards, planks, and timbers. Oak lumber is imported for such uses as flooring, inside finish, furniture, cabinet work, bank, store, and office fixtures, paneling, wainscoting, picture molding, and doors. The black walnut, cherry, and tulip poplar from the East, the prima vera, poplar, and mahogany from Mexico, the koa from Hawaii, the red bean from Australia, and the Siberian oak from Japan also go very largely into special lumber orders like the oak. Basswood is used in the upper parts of wagons and carriages and especially for work in pyrography.

A California-grown eucalypt, the blue gum, has been made into insulator pins which have proved very satisfactory. It is also used quite extensively for cordwood, to some extent for piling, and is being tried in the form of veneer for furniture and interior finish. It is very probable that the use of blue gum in California will be considerably enlarged in the near future. The black cottonwood is used princi-

pally for fruit baskets, and for this purpose is cut into veneer one-twentieth of an inch thick. Some is made also into wagon stock.

The cost of all hardwoods is high. Ash and plain oak average $100 per thousand board feet, while quartered oak and hickory average $125 per thousand. Iron bark brings about $105 per thousand, and Siberian oak about $80 per thousand. This includes the cost of transportation.

SUGGESTED USES FOR TANBARK OAK.

Up to the present time little has been known of the possibilities of tanbark oak. The feeling has been that the wood was subject to checking and warping to such a degree as to render its use impracticable. All hardwoods are more or less subject to these defects, and it is believed that the difficulties encountered in seasoning tanbark will prove no greater than those which have been overcome in some of the eastern hardwoods. In fact, the experiments made by the Forest Service, which it must be remembered were conducted under unfavorable conditions, showed that the wood can be seasoned in a dry kiln in such a manner that more than half of it will be satisfactory material and only 10 per cent badly checked.

The lumber company mentioned as manufacturing tanbark oak flooring has had several experimental floors laid and in all cases they have proved satisfactory under hard usage. About 200,000 feet of flooring has been made up, and about 1,000,000 feet of lumber is in process of drying. In sawing this lumber the regular equipment of a redwood mill was used. Tanbark oak seems well suited for flooring. It has a pleasing grain and color and the necessary hardness. By using short pieces of the same length, say, from 9 to 18 inches, grooved and tongued on the ends, as well as on the sides, the material can be closely utilized. In laying a floor from such pieces a pleasing effect is obtained by having each strip of flooring break joints with the strips on each side and by alternating the light and dark pieces in each strip.

It is quite probable that tanbark oak will prove suitable for tight cooperage. There seems to be a feeling at present that a contained liquid would be affected by the wood, but so far as is known the wood has not yet been given a fair trial. In regard to the tannin in the wood, there is said to be a higher percentage in the case of eastern white oak (1.32 per cent) [1] than in the case of tanbark oak (0.63 per cent). Of course there may be other constituents that render tanbark oak unfit for use as a liquid container, but it is at least worthy of a trial.

As an inside finish, tanbark oak has the beautiful figured grain of other oaks, and there is apparently no reason why it should not give

[1] See Yearbook for 1902, U. S. Dept. of Agriculture, article entitled "Chemical Studies of Some Forest Products of Economic Importance."

satisfaction. This seems to be proved by a number of finished specimens of the wood now in the Forest Service offices in San Francisco.

The mechanical properties of tanbark oak render it suitable for wagon and car stock. In bending and crushing strength it compares favorably with eastern oak and hickory, which have for so long been used in such construction. In drying it shrinks about the same amount as red oak. Tanbark-oak bolsters for logging trucks are in use and giving satisfaction. A number of strips of tanbark oak 1½ inches thick, 4 inches wide, and 6 feet long were steamed and bent at a wagon factory in Oakland, Cal., with as good results as with white oak under similar treatment.

Under present methods the price of bark f. o. b. track in the regions of production averages $15 per cord. The fuel wood from the trees that furnished this cord of bark would amount to about 2 cords, worth on an average $5 per cord delivered at the nearest railroad. Bark and cordwood together, then, would be worth $25. The 2 cords of fuel would amount to about 1,600 feet board measure. If half of this is suitable for boards, it is evident that with the present price of oak lumber the returns would be greater if the tree were cut into lumber rather than cordwood.

In conclusion, there seems to be no good reason why tanbark oak should not take its place in the Pacific coast hardwood market for many if not all the purposes for which eastern hardwoods are now imported; and if this is true lumber companies owning tanbark-oak stumpage could profitably take up the utilization of this wood as lumber. In California, particularly, where such large quantities of hardwood are imported at a high and constantly increasing cost, a native oak with both properties and appearance that compare favorably with eastern oaks ought not to be allowed to go to waste, but should at least be given a commercial trial.

APPENDIX.

DISTRIBUTION OF TANNIN IN TANBARK OAK.

By C. D. Mell.

Tannin is found in most plants and almost exclusively in the living cells, though there are some in whose cells it is not found, such as European hackberry (*Celtis australis* Linn.), white mulberry (*Morus alba* Linn.), black elder (*Sambucus canadensis* Linn.), honey locust (*Gleditsia triacanthos* Linn.), black locust (*Robinia pseudacacia* Linn.), and laburnum (*Cytisus laburnum* Linn.). It is always in the form of a solution in the cells and not in the cell membrane, nor in its primary membrane. Tannin, chlorophyll, and starch are closely associated; tannin and chlorophyll together in collenchyma and phelloderm, and tannin and starch together in the same cells in pith rays. Tannin is most abundant in the elements outside the cambium, and in a few cases it is present sparingly in wood fibers.

An investigation of the tannin contents of a number of trees shows that several of the elements of tanbark oak have tannin distributed through them, as shown in Table 12. Tannin is present in such of the structural elements of each wood as are indicated by the letter x. The small circle indicates that the tannin content in the element so marked is very small, and of no importance in connection with commercial operations.

Table 12.—*Elements of pith, wood, and bark of trees containing tannin.*

Species.	Structural elements containing tannin.													
	Epidermal cells.	Cork-cambium.	Phelloderm.	Primary cortex.	Sclerenchyma (stone cells).	Bast parenchyma.	Pith ray cells in bast.	Interfascicular cambium.	Fascicular cambium.	Wood parenchyma.	Wood fibers.	Pith-ray cells.	Parenchyma cells of medullary sheath.	Living cells of pith.
Quercus densiflora Hook. and Arn. (tanbark oak)	x	x	x	x	x	....	x	x	....	....	....	x°	x°	....
Alnus glutinosa (L.) Gaertn. (black alder)	....	x	x	x	x	x	x	x	....	x	....	x	....	x
Betula papyrifera Marsh. (paper birch)	....	x	x	x	x	x	x	x	....	x°	....	....	....	x
Carpinus caroliniana Walt. (blue beech)	....	x	x	x	x	x°	x	....	....	....	....	x°	....	....
Corylus americana Walt. (hazel)	x	x	x	x	x	x	....	x	....	....	....	....	....	....
Salix purpurea Linn. (purple willow)	x	x	x	x	x	x	x	x	....	x	....	x	x	x
Platanus occidentalis Linn. (sycamore)	....	x	x	x	....	....	....	....	....	x°	....	x°	....	....
Hamamelis virginiana Linn. (witch hazel)	....	x	x	x	x	....	....	x	....	x	....	x	....	....
Acer platanoides Linn. (Norway maple)	....	x	x	x	x	x	x	x	x	....	....	x	....	....
Rhus cotinus Linn. (young fustic)	x	x	x	x	....	x	x	x	x	x	....	x	....	....
Pyrus communis Linn. (pear)	....	x	x	x	....	x	....	x	....	x°	....	x	....	....
Eucalyptus cordata Labill. (gum)	....	....	....	x	....	....	x	....	....	....	....	x	....	....
Ribes rubrum Linn. (currant)	....	x	x	....	....	x	....	....	....	....	....	x	....	....
Syringa vulgaris Linn. (lilac)	....	x	x	x	....	x	....	x	....	x	x°	x	x°	x
Fraxinus americana Linn. (white ash)	....	x	x	x	....	x	x	x	x	x	....	x	....	x

To determine correctly the distribution of tannin in plant tissue, it is best to fix the tannin content in such a manner that it becomes hard, compact, and easily recognizable under the microscope in transverse and longitudinal sections. Tannin hardens into a compact mass when treated with potassium bichromate and, in transmitted light, has an intense red-brown color.

The ultimate twigs, obtained from growing trees, are cut lengthwise through the pith and are allowed to dry for 12 hours in a room of ordinary temperature. Then they are soaked in a solution of potassium bichromate for a week before the sections are cut. The material must be treated before it is sectioned, otherwise the tannin content will be distributed by the knife into elements where it does not naturally occur. The color does not change when the sections are mounted in glycerin, so the sections may be preserved in this way for classroom or other demonstration work. The first 8 or 10 sections should be discarded, because they will include the outer cells coated by tannin that oozed out when the twigs were first cut; and they are likely to be disappointing because they will not show the undisturbed tannin content. The cells in which tannin occurs will be filled with a compact red-brown mass (Pls. IX and X); or there may be only a few small red-brown globules, as in the pith ray cells of European alder (*Alnus glutinosa*, L. Medic.).

An investigation of this sort shows that tannin is present in the twigs of tanbark oak as well as in the older bark, and that tanning extract could be made from the twigs and smaller branches, as in the case of the eastern chestnut (*Castanea dentata*). Yet there is but little tannin in the wood-parenchyma elements of the heartwood of tanbark oak, so that tanning-extract can not be got by chipping the wood and subjecting it to tanning-extract processes, as in the case of the chestnut.

O